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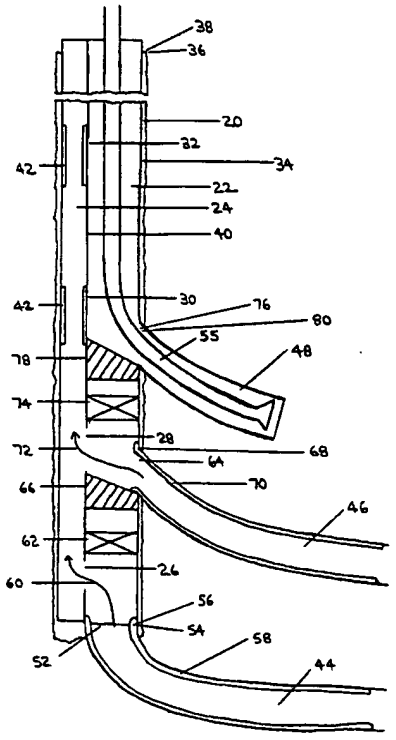

(57) Abrégé/Abstract:
An method and apparatus for use in completing a borehole. The apparatus includes a primary conduit assembly which in turn includes a tubular casing string, a tubular production string and at least one primary conduit junction for providing communication between the casing string and the production string. The method includes the steps of inserting the primary conduit assembly into a primary borehole, drilling a lateral borehole from the casing string and then removing the drilling tool, following which fluids may be produced from the lateral borehole via the primary conduit junction and the production string.

ABSTRACT

An method and apparatus for use in completing a borehole. The apparatus includes a primary conduit assembly which in turn includes a tubular casing string, a tubular production string and at least one primary conduit junction for providing communication between the casing string and the production string. The method includes the steps of inserting the primary conduit assembly into a primary borehole, drilling a lateral borehole from the casing string and then removing the drilling tool, following which fluids may be produced from the lateral borehole via the primary conduit junction and the production string.

METHOD AND APPARATUS FOR USE IN COMPLETING A BOREHOLE

TECHNICAL FIELD

This invention relates to a method and apparatus for use in completing a borehole.

BACKGROUND OF THE INVENTION

Subterranean drilling technology provides for the drilling of boreholes from the earth's surface to a point beneath the surface. In the past, boreholes were typically drilled vertically or near-vertically due to limitations inherent in both drilling equipment and drilling techniques. More recent drilling technology, however, has provided for the drilling of directional boreholes in which the direction of a borehole is other than vertical over all or a portion of its length.

Directional drilling equipment and techniques have developed from the need to control the path of a borehole so that it either intercepts or avoids identified subterranean targets. Horizontal drilling has developed as a specialized form of directional drilling in which the borehole is substantially horizontal over all or a portion of its length. Vertical and directional boreholes are commonly drilled for both exploration and production purposes. Horizontal boreholes on the other hand are typically used mainly for production purposes because they can provide increased contact between the borehole and subterranean formations (such as those containing petroleum reserves) over the length of the horizontal borehole.

Contemporary boreholes often include a combination of vertical and directional sections. Sometimes directional or horizontal boreholes are drilled as extensions from existing vertical boreholes in order to increase production from older wells. Alternatively, the original design of a well may include a combination of vertical and directional sections.

In both cases there will typically exist a primary borehole which extends from the earth's surface. From this primary borehole one or more lateral boreholes may be drilled. Usually, but not always, the primary borehole is a vertical or near-vertical borehole and the lateral boreholes are directional or horizontal boreholes.

In any event, there will exist a location of intersection between the primary borehole and a lateral borehole which is commonly referred to as a "lateral junction". Boreholes which include more than one lateral borehole are commonly referred to as "multilateral boreholes". Multilateral boreholes which are intended for use as wells are commonly referred to as "multilateral wells". Multilateral wells are therefore created from multilateral boreholes which by definition include more than one lateral junction.

There are special challenges faced in completing boreholes which include lateral junctions, which challenges may be translated into a number of criteria for assessing and describing lateral junctions.

These criteria include first, the degree of connectivity between the primary borehole and the lateral borehole (i.e., sealing of the lateral junction), second, the degree of accessibility of the lateral borehole from the primary borehole for the purpose of enabling subsequent borehole operations in the lateral borehole (i.e., the ability to

reenter the lateral borehole selectively), and third, the degree of flow control over production or injection fluid moving across the lateral junction (i.e., isolation of the lateral borehole). Of these three criteria, the degree of connectivity and the degree of accessibility are almost always important, while the degree of flow control may or may not be important and is typically achieved using completion apparatus such as packers and tubing strings rather than by the lateral junction itself.

Ideally, the degree of connectivity of a lateral junction is such that pressure integrity of the lateral junction is achieved without isolation of the lateral borehole with completion apparatus. In addition, the lateral borehole is preferably accessible for selective reentry from the primary borehole in as simple a manner as is possible.

There are additional challenges inherent in the completion of lateral junctions in multilateral wells.

One additional challenge to multilateral wells, where each lateral borehole may be considered as a separate well with different characteristics, is that it would be desirable to have the ability to control each lateral borehole independently.

For example, it may be necessary to cease production in one lateral borehole in order to perform servicing operations in that lateral borehole, but it would be desirable to be able to continue to produce fluids from other lateral boreholes while this is occurring. It would also be desirable to have the ability to drill new lateral boreholes while continuing to produce fluids from one or more of the existing lateral boreholes. Unfortunately, this is problematic if all of the lateral boreholes connect with a single primary borehole. As a result, it may be necessary to cease production in all of

the lateral boreholes while one of the existing lateral boreholes is being serviced or while new lateral boreholes are being drilled.

One possible solution is to segregate the primary borehole to provide a separate path in the primary borehole to each of the lateral boreholes. This solution, however, becomes less feasible as the number of lateral boreholes increases, since the allowable maximum size of each of the segregated paths will decrease as the number of required paths increases in order that all of the segregated paths may be contained within the primary borehole.

A second additional challenge to multilateral wells is that sealing the lateral junction and facilitating selective reentry into lateral boreholes is more complicated with multilateral wells than it is with wells having only one lateral borehole. The reason for this is that the apparatus that is required to provide for sealing and reentry may partially obstruct the primary borehole, making it more difficult to access those lateral junctions below the most proximal lateral junction. Efforts to minimize the amount of this obstruction tend to compromise either the integrity of the lateral junction or the ease with which selective reentry of the lateral borehole may be achieved.

One potential solution to some of the challenges associated with the completion of lateral junctions in multilateral wells is proposed in PCT International Publication No. WO 98/49424 (Den Boer et al). Den Boer teaches a well system which comprises a plurality of entrance points at the earth surface and a system of underground wellbores which provide a subsurface connection between the entrance points so that the production of oil and/or gas can continue via at least one of the entrance points while drilling, servicing, maintenance and/or monitoring equipment is moved and operated via another entrance point.

The system in Den Boer contemplates two primary boreholes interconnected by one or more lateral boreholes. Other lateral boreholes may be associated with either of the primary boreholes without interconnecting the two primary boreholes. Valves are located in those of the lateral boreholes which communicate with a first primary borehole to selectively permit or prevent fluids from moving from the lateral boreholes into the first primary borehole. When these valves are closed, production from the first primary borehole is prevented and equipment may be moved through the first primary borehole. Meanwhile, some production of fluids may continue from a second primary borehole to the extent that such fluids are located on the "second primary borehole side" of the valves.

Although it is stated in Den Boer that the two primary boreholes may be located in a single vertical well, the two primary boreholes are always interconnected with a downhole borehole so that a closed loop is formed by the two primary boreholes and the interconnecting downhole borehole. In this way, the two primary boreholes are independent and may be isolated from each other with the use of the valves.

The system described in Den Boer has a number of disadvantages. First, it is relatively complex to construct, since it requires the application of precision drilling techniques to achieve the intersection of a primary borehole by a lateral borehole (or vice versa) in order to create the closed loop. Second, it requires the actuation of a relatively complex system of valves which are located in a plurality of locations throughout the well system in order to prepare the first primary borehole for equipment to be passed through it for servicing, drilling, maintenance or monitoring operations. Third, the effectiveness and thoroughness of the borehole operations conducted via the first primary borehole is limited by the position of the valves which isolate the first primary borehole from the second primary borehole. Finally, efficient

and complete production from the well system (other than when borehole operations are being conducted in the first primary borehole) appears to contemplate production from both the first primary borehole and the second primary borehole, thus increasing the overall cost of the well in comparison with a well having only one primary borehole and one wellhead.

There remains a need for an apparatus and method for use in completing a borehole which facilitates effective connectivity (sealing) of lateral junctions, simple selective reentry of lateral boreholes, and which is capable of allowing production of fluids from one or more lateral boreholes via a single production string while borehole operations are being conducted in existing lateral boreholes or while new lateral boreholes are being drilled.

SUMMARY OF THE INVENTION

The present invention is a method and apparatus for use in completing a borehole, where the borehole is comprised of a primary borehole and may be further comprised of one or more lateral boreholes. The purpose of the invention is to facilitate the production of fluids from the borehole as well as the conduct of borehole operations from the primary borehole. Preferably the invention facilitates the simultaneous production of fluids from the borehole and conduct of borehole operations in the borehole.

The term "borehole operations" as used herein includes any operations conducted from the primary borehole which require the passage of equipment through the primary borehole. Such borehole operations may include, but are not limited to

drilling, servicing, maintaining, repairing, and evaluating the borehole as well as monitoring conditions within or surrounding the borehole.

The apparatus of the invention includes a primary conduit assembly comprised of a casing string and a production sting, which primary conduit assembly is adapted for placement in a single primary borehole. The primary conduit assembly provides for some communication between the casing string and the production string. Preferably, the casing string also provides for some communication between the borehole and the casing string.

The function of the primary conduit assembly is to separate and distribute between the casing string and the production string the various functions which would typically be performed in a conventional primary casing string. For example, the casing string may be utilized for drilling of lateral boreholes and for establishing connectivity between the primary borehole and lateral boreholes. The production string may be utilized for the production of fluids to the surface and for achieving reentry into lateral boreholes as required for borehole operations. By separating functions between the casing string and the production string, functions such as connectivity between the primary borehole and lateral boreholes and selective reentry into lateral boreholes may be achieved with less design compromise than if these functions were being performed in a single primary casing string.

The method of the invention includes inserting the primary conduit assembly into a primary borehole and then using the primary conduit assembly to facilitate completion of lateral junctions, the drilling of lateral boreholes, the conduct of borehole operations, and/or the production of fluids from the borehole.

In an apparatus aspect, the invention is an apparatus for use in completing a borehole, the borehole comprising a primary borehole, the apparatus comprising a primary conduit assembly, the primary conduit assembly being comprised of:

(a) a tubular casing string extending into the primary borehole from a borehole entrance location;

(b) a tubular production string extending alongside the casing string and into the primary borehole from the borehole entrance location; and

(c) at least one primary conduit junction contained within the primary borehole, wherein the primary conduit junction provides for communication between the casing string and the production string.

The primary borehole may be a vertical borehole, a directional borehole, a horizontal borehole, or a combination thereof. The surface end of the primary borehole may located at the earth's surface or it may be submerged by water.

The casing string and the production string may be in any configuration relative to each other as long as the primary conduit assembly can be inserted into the primary borehole. Preferably the casing string and the production string are configured so that they are alongside each other and not so that one is inside the other. The casing string and the production string are preferably substantially parallel to each other and in the preferred embodiment, are contiguous along all or most of their respective lengths in order to minimize the cross-sectional dimensions of the primary conduit assembly.

The primary conduit junction may be comprised of any structure or apparatus which is capable of providing communication between the casing string and the production string. Preferably the primary conduit junction is contained within the primary borehole so that the entire primary conduit assembly can be lowered into the primary borehole as a unit and so that no further borehole need be constructed to provide communication between the casing string and the production string. Preferably also the primary conduit junction permits the passage of equipment therethrough as may be necessary for the performance of borehole operations from the production string. In the preferred embodiment, the primary conduit junction is formed as a production window at the interface between the contiguous casing string and production string.

The casing string and the production string may be of any size suitable for insertion in the primary borehole, but preferably their sizes are maximized in order to make maximum usage of the primary borehole. In the preferred embodiment, the casing string is larger in cross-section than is the production string to facilitate the passage of drilling equipment through the casing string.

Preferably the casing string defines at least one casing port. The casing port may be comprised of any structure or apparatus which is capable of providing communication between the borehole and the casing string. For example, the casing port may be comprised of perforations in the casing string or it may be comprised of a transition junction between a vertical or near-vertical portion of the primary borehole and a directional or horizontal section of the primary borehole (sometimes referred to as a "main lateral" or a "primary lateral").

Preferably, however, the casing port is comprised of a casing window which is either preformed in the primary conduit assembly (and perhaps temporarily

covered with a sleeve or similar device) or is milled after the primary conduit assembly is lowered into position in the primary borehole. This casing window in turn preferably forms part of a lateral junction when a lateral borehole is drilled in the proximity of the casing port.

Although the apparatus is effective with only one primary conduit junction and one casing port, preferably the primary conduit assembly is comprised of a plurality of longitudinally spaced primary conduit junctions and the casing string is comprised of a plurality of longitudinally spaced casing ports so that the apparatus is further comprised of a plurality of communication paths between the casing ports and the production string, with each communication path being defined by one of the casing ports, the casing string, one of the primary conduit junctions and the production string.

The communication paths are preferably isolated from each other in the casing string and may also be isolated from each other in the production string in order to facilitate segregated production to the surface from the communication paths. In the preferred embodiment, however, the communication paths are commingled once they reach the production string.

The communication paths may be isolated from each other in the casing string by any structure or apparatus. Preferably the apparatus further comprises a plurality of casing sealing devices located in the casing string for this purpose. These casing sealing devices may be comprised of any suitable structure or apparatus which can seal the casing string. In the preferred embodiment the casing sealing devices are packers or bridge plugs which are positioned in the casing string so that two packers or bridge plugs straddle each communication path.

Preferably each casing port and its associated primary conduit junction are located relative to each other so that each communication path is as direct as possible. Where the casing port is comprised by a lateral junction between the primary borehole and a lateral borehole, then the lateral junction is preferably located relative to its associated primary conduit junction so as to facilitate the conduct from the production string of borehole operations in the lateral borehole via the primary conduit junction.

One of the features of the preferred apparatus form of the invention is that drilling and completion of the primary borehole and lateral boreholes may be conducted from the casing string while production and subsequent borehole operations may be conducted from the production string.

As a result, each lateral junction may be completed without providing for access via the casing string to locations in the primary borehole below the lateral junction. In addition, the production string may be kept relatively free from obstructions to facilitate production and subsequent borehole operations. This feature therefore results in a number of advantages.

First, casing deflection devices which are typically inserted into conventional casing strings to aid in the drilling of lateral boreholes may be left in the casing string after drilling has been completed to assist in subsequent reentry into the lateral borehole via the production string. In the preferred embodiment, the apparatus is further comprised of a casing deflection device located in the casing string adjacent to one or more of the lateral junctions.

Second, connectivity between the casing string and lateral borehole liners may be established using equipment which extends into the casing string, thus lessening the need for specialized equipment and potentially resulting in a higher quality lateral junction.

Third, the casing sealing devices may be relatively permanent structures which may provide an improved seal over conventional removable sealing devices.

In a method aspect, the invention is a method for use in drilling and completing a borehole, the borehole comprising a primary borehole, the method comprising the following steps:

(a) inserting into the primary borehole a primary conduit assembly comprising a tubular casing string and a tubular production string so that the casing string and the production string extend alongside each other from a borehole entrance location;

(b) drilling a first lateral borehole by inserting a drilling tool into the casing string at the borehole entrance location such that the drilling tool exits the casing string at a first casing port defined by the casing string so that the first casing port is comprised by a first lateral junction; and

(c) removing the drilling tool from the casing string.

Preferably the method further comprises the step of cementing the primary conduit assembly in the primary borehole. The cementing step may be performed at any time after the primary conduit assembly is positioned in the primary

borehole. Preferably the cementing step is performed before the first lateral borehole is drilled.

The method may further comprise additional steps performed either before or after the drilling of the first lateral borehole.

First, the method may further comprise the step of inserting a first casing deflection device in the casing string adjacent to the first casing port before the step of drilling the first lateral borehole. The method may also further comprise the step of removing the first casing deflection device from the casing string after the first lateral borehole is drilled. In the preferred embodiment the first casing deflection device is not removed from the casing string after the first lateral borehole is drilled.

Second, the method may further comprise the step of forming the first casing port before the step of drilling the first lateral borehole. This step is necessary where the first casing port must be milled in the casing before drilling can take place.

Third, the method may further comprise the step of running a first liner into the first lateral borehole after the first lateral borehole is drilled. This step is preferably performed by inserting the first liner into the casing string such that it exits the casing string at the first lateral junction and enters the first lateral borehole. The method may also comprise the step of connecting the first liner to the casing string after it has been positioned in the first lateral borehole.

The first liner may be comprised of any conduit which can be inserted in the first lateral borehole, including casing, tubing, coiled tubing, sleeves and other

suitable conduits. The first liner may also be perforated or slotted and may be equipped with a screen for preventing debris from entering the first liner.

The first liner may be connected to the casing string in any manner, depending upon the required integrity of the lateral junction. As previously indicated, the invention in its preferred form provides significant flexibility in achieving connectivity between the first liner and the casing string because minimizing obstruction of the casing string is not necessarily the main consideration.

The primary conduit assembly preferably provides a first communication path between the first lateral junction and the production string to facilitate production of fluids from the first lateral borehole and the conduct of borehole operations in the first lateral borehole from the production string.

Preferably the first communication path is provided by the first lateral junction, the casing string, a first primary conduit junction and the production string. The first communication path may be established either before or after the drilling of the first lateral borehole. Preferably the first communication path is established after the first lateral borehole has been drilled and the first lateral junction has been completed in order to minimize the amount of debris which enters the production string.

The first primary conduit junction may be preformed in the primary conduit assembly or may be formed after the primary conduit assembly is lowered into position in the primary borehole. The method preferably further comprises the step of opening the first primary conduit junction to establish the first communication path.

The opening step may be comprised of drilling, milling or otherwise forming the first primary conduit junction if it has not been preformed. If the first primary conduit junction has been preformed in the primary conduit assembly, it is preferably sealed to prevent debris from entering the production string from the casing string. Preferably the first primary conduit junction is sealed with a first isolation sleeve, in which case the opening step may be comprised of removing the first isolation sleeve from the primary conduit assembly. The first isolation sleeve may be located in either the production string or the casing string but is preferably located in the production string so that it may be removed via the production string.

The method may further comprise the step of sealing the casing string with a first sealing device proximally of the first primary conduit junction and the first lateral junction. This sealing of the casing string prevents debris from moving down through the casing string to the location of the first lateral borehole and also isolates the first communication path from that portion of the casing string which is above the first sealing device.

Once the first communication path has been established, the method may further comprise the step of producing a fluid from the borehole via the first communication path and the production string. The production of fluid may be assisted by a pump or other lift apparatus positioned in the production string.

The method has been described above as it relates to the drilling of a single lateral borehole and the establishment of a single communication path. The method of the invention may, however, comprise repeating some or all of the method steps described above in order to provide for a plurality of lateral boreholes and communication paths. In theory, there is no limit to the number of lateral boreholes which may be drilled from a single primary conduit assembly using the method of the

invention. Where the method is used for drilling a plurality of lateral boreholes from a primary conduit assembly each successive lateral borehole drilled should be located proximally of the previous lateral borehole drilled.

As noted with the apparatus aspect of the invention, a first feature of the preferred embodiment of the invention is that casing deflection devices, casing sealing devices, and equipment used to establish connectivity between the primary borehole and various lateral boreholes may be comprised of relatively permanent installations and conventional assemblies rather than specialized equipment, since subsequent access to and reentry into lateral boreholes is preferably achieved via the production string instead of via the casing string.

A second feature of the preferred embodiment of the invention is that a fluid may be produced from the borehole via one or more communication paths and the production string simultaneously. The communication paths may be segregated in the production string or may be commingled in the production string. Preferably the communication paths are commingled in the production string so that the design of the production string can be simplified.

A third feature of the preferred embodiment of the invention is that a fluid may be produced from the borehole via one or more of the communication paths and the production string at the same time that drilling of a new lateral borehole is occurring from the casing string. This feature is important for maximizing revenue streams from boreholes and for producing fluids from many lateral boreholes using limited surface locations.

Finally, a fourth feature of the preferred embodiment of the invention is that it is possible that a fluid might be produced from the borehole via one or more of the communication paths and the production string at the same time that borehole operations are being conducted in one or more lateral boreholes via the production string.

It should also be noted that in both the apparatus and method aspects of the invention communication paths may be established in the primary conduit assembly without a lateral borehole being drilled. For example, one or more "levels" of the primary borehole may include a communication path in which the casing port communicates with the primary borehole, in which case the casing port is preferably comprised of a casing window or a perforation or perforations in the casing string.

BRIEF DESCRIPTION OF DRAWINGS

Embodiments of the invention will now be described with reference to the accompanying drawings, in which:

Figure 1 is a longitudinal sectional view of a primary conduit assembly according to a preferred embodiment of the invention in place inside a borehole.

Figure 2 is a longitudinal sectional view of a primary conduit assembly according to a preferred embodiment of the invention in place inside a borehole, including two existing lateral boreholes and depicting a drilling tool drilling a third new lateral borehole.

Figure 3 is a longitudinal sectional view of a primary conduit assembly according to a preferred embodiment of the invention in place inside a borehole, including four existing lateral boreholes.

Figure 4 is a transverse cross-sectional view of a primary conduit assembly taken along section line 4-4 in Figure 3, showing a primary conduit junction and a casing port.

Figure 5 is a longitudinal sectional view of a primary conduit assembly according to a preferred embodiment of the invention in place inside a borehole, including four existing lateral boreholes and depicting equipment in place inside one of the lateral boreholes for the conduct of borehole operations in the lateral borehole.

DETAILED DESCRIPTION

The invention includes an apparatus for use in completing a borehole and a method for use in drilling and completing a borehole, wherein the borehole includes a primary borehole and may include one or more lateral boreholes.

Referring to Figure 1, the apparatus is comprised of a primary conduit assembly (20). The primary conduit assembly (20) is comprised of a tubular casing string (22), a tubular production string (24) and at least one primary conduit junction.

The number of primary conduit junctions will depend upon the design plan for the borehole. In the preferred embodiment the primary conduit assembly (20) includes a first primary conduit junction (26), a second primary conduit junction (28), a

third primary conduit junction (30) and a fourth primary conduit junction (32). The function of the primary conduit junctions (26,28,30,32) is to provide communication between the casing string and the production string.

In Figures 1, 2, 3 and 5, the primary conduit assembly (20) is shown in position in a primary borehole (34). The casing string (22) and the production string (24) extend into the primary borehole (34) from a borehole entrance location (36).

The borehole entrance location (36) provides independent paths within the primary borehole (34) for both the casing string (22) and the production string (24). In the preferred embodiment the borehole entrance location (36) is located near a surface end (38) of the primary borehole (34), such as at a wellhead (not shown). The borehole entrance location (36) may, however, be located above the surface end (38) of the primary borehole (34), as might be the case if the borehole is offshore and the surface end (38) of the primary borehole (34) is located underwater.

The casing string (22) and the production string (24) extend alongside each other (and not one inside the other) into the primary borehole (34) from the borehole entrance location (36) in order to establish two separate paths in the primary borehole (34).

Referring to Figure 4, in the preferred embodiment the casing string (22) and the production string (24) are substantially parallel to and contiguous with each other over their entire length to form an interface (40) between them, and are welded together. This configuration provides a relatively compact primary conduit assembly (20) which minimizes the required size of the primary borehole (34).

In the preferred embodiment, drilling and completion operations are carried out in the borehole via the casing string (22) while production of fluid and subsequent borehole operations are conducted via the production string (24). As a result, in the preferred embodiment the casing string (22) is sized to accommodate drilling and completion equipment while the production string (24) and the primary conduit junctions (26,28,30,32) are sized to accommodate expected production flowrates and the equipment typically used in post-drilling borehole operations. In the preferred embodiment the casing string (22) is larger in cross-section than the production string (24).

Referring to Figures 1 and 2, in the preferred embodiment the primary conduit junctions (26,28,30,32) are preformed in the primary conduit assembly (20) before the primary conduit assembly (20) is inserted into the primary borehole (34), but are equipped with removable isolation sleeves (42) in order to prevent debris from entering the production string (24) or production fluids from entering the casing string (22) while drilling and completion operations are being conducted in the casing string (22).

The isolation sleeves (42) may be positioned in either the casing string (22) or the production string (24). In the preferred embodiment the isolation sleeves (42) are positioned in the production string (24) to minimize obstruction of the casing string (22) and are removable via the production string (24) in order to "open" the primary conduit junctions (26,28,30,32). Alternatively, the primary conduit junctions (26,28,30,32) may be formed and opened simultaneously by milling or other techniques.

The primary conduit junctions (26,28,30,32) are contained within the primary borehole (34) so that the primary conduit assembly (20) may be inserted in the

primary borehole (34) as a unit without the need for drilling or otherwise creating the primary conduit junctions (26,28,30,32) outside of the primary borehole (34).

Referring to Figure 4, in the preferred embodiment the primary conduit junctions (26,28,30,32) are comprised of production windows which are formed at the interface (40) between the casing string (22) and the production string (24). This configuration further adds to the compactness of the primary conduit assembly (20), since the primary conduit junctions (26,28,30,32) are between the casing string (22) and the production string (24) and take up no additional space in the primary borehole (34). If the casing string (22) and the production string (24) are not contiguous with each other, the primary conduit junctions (26,28,30,32) are preferably comprised of junction conduits (not shown) between the casing string (22) and the production string (24).

Figure 1 depicts the primary conduit assembly (20) in place in the primary borehole (34) before any drilling or completion operations have been conducted from the casing string (22), while Figure 2 depicts the primary conduit assembly (20) after some drilling and completion operations have been conducted from the casing string (22).

In the preferred embodiment, the primary conduit assembly (20) will be cemented into the primary borehole (34) before any drilling or completion operations are conducted from the casing string (22). As used herein, the term "cementing" refers to any procedure by which the primary conduit assembly (20) may be fixed in the primary borehole (34), and includes conventional cementing techniques using cement and other bonding agents.

Figure 2 depicts the primary conduit assembly (20) in place in the primary borehole (34) following drilling and completion of a first lateral borehole (44) and a second lateral borehole (46) and during drilling of a third lateral borehole (48). Figure 3 depicts the primary conduit assembly (20) in place in the primary borehole (34) following drilling and completion of the first lateral borehole (44), the second lateral borehole (46), the third lateral borehole (48) and a fourth lateral borehole (50). The components of the borehole depicted in Figure 3 are best described with reference to the preferred method of construction of the borehole depicted in Figure 3.

The first lateral borehole (44) is the most distally located lateral borehole. The first lateral borehole (44) is drilled so that it extends from a first casing port (52). In the Figures the first casing port (52) is comprised of a distal end (54) of the casing string (22) so that the first lateral borehole (44) may be described as the "main lateral borehole" or the "primary lateral borehole".

Alternatively the first casing port (52) may be comprised of a casing window defined by the casing string (22), in which case the first lateral borehole (44) is drilled so that it extends from the casing window. If the first casing port (52) is comprised of a casing window, the casing window may be formed by milling or other suitable procedure either before or after the primary conduit assembly (20) is inserted into the primary borehole (34).

If the first casing port (52) is comprised of a casing window, then the drilling of the first lateral borehole (44) may require that a first casing deflection device (not shown) such as a whipstock first be inserted in the casing string (22) adjacent to the casing window to deflect a drilling tool (55) out of the casing window. The first casing deflection device may or may not be necessary if the first casing port (52) is comprised of the distal end (54) of the casing string (22). In any event, if the first casing deflection

device is required in order to drill the first lateral borehole (44), it may either be removed from the casing string (22) after the first lateral borehole (44) has been drilled and completed or it may be left in the casing string (22) permanently, In the preferred embodiment, the first lateral borehole extends from the distal end (54) of the casing string (22) and is drilled without the use of the first casing deflection device.

After the first lateral borehole (44) has been drilled the first casing port (52) is part of and comprised by a first lateral junction (56) between the casing string (22) and the first lateral borehole (44).

In the preferred embodiment a first liner (58) is run into the first lateral borehole (44) to complete the first lateral borehole (44). The first liner (58) may be optional depending upon the requirements of the borehole. The first liner (58) is run into the first lateral borehole (44) by inserting the first liner (58) into the casing string (22) such that it exits the casing string (22) at the first lateral junction (56) and enters the first lateral borehole (44). The first liner (58) may where applicable be deflected into the first lateral borehole (44) by the first casing deflection device.

The first liner (58) is preferably connected with the casing string (22) at the first lateral junction (56) to establish connectivity between the primary borehole (34) and the first lateral borehole (44) and thus complete the first lateral junction (56). The connection between the casing string (22) and the first liner (58) may be established in any manner and may include equipment and apparatus which extend into the casing string (22). As a result, a high degree of connectivity may be established at the first lateral junction (56) without the need for special equipment for minimizing the obstruction of the casing string (22).

The borehole communicates with the casing string (22) through the first casing port (52). More specifically, the first lateral borehole (44) communicates with the casing string (22) through the first casing port (52).

When the first primary conduit junction (26) is opened the first casing port (54), the casing string (22), the first primary conduit junction (26) and the production string (24) define a first communication path (60) through the primary conduit assembly (20). Referring to Figure 1, in the preferred embodiment the first primary conduit junction (26) may be opened by removing the isolation sleeve (42) which is covering it. Alternatively, the first primary conduit junction (26) may be simultaneously formed and opened by milling or other suitable procedure.

In the preferred embodiment, the first casing port (52) and thus the first lateral junction (56) is located relative to the first primary conduit junction (26) so as to facilitate the conduct from the production string (24) of borehole operations in the first lateral borehole (44) via the first primary conduit junction (26).

The first communication path (60) is further defined in the preferred embodiment by a first casing sealing device (62) located proximally of the first primary conduit junction (26) and the first casing port (52). The first casing sealing device (62) may be comprised of any suitable packer, bridge plug or other structure or apparatus which is capable of sealing the casing string (22). The first casing sealing device (62) may be removable or may be a relatively permanent installation.

The function of the first casing sealing device (62) is first, to isolate the first communication path (60) from that portion of the casing string (22) which is proximal to the first casing sealing device (62) and second, to prevent the first communication path

(60) from being contaminated by debris generated during drilling and completion of the second lateral borehole (46). The first casing sealing device (62) is installed in the casing string (22) after the first liner (58) has been inserted in the first lateral borehole (44) and preferably after the first lateral junction (56) has been completed, although it may be possible to complete the first lateral junction (56) from the production string (24) after the first casing sealing device (62) has been installed.

The second lateral borehole (46) is located proximally of the first lateral borehole (44) and in the preferred embodiment is drilled after the first casing sealing device (62) has been installed in the casing string (22). The second lateral borehole (46) is drilled from a second casing port (64) comprised of a casing window defined by the casing string (22). The casing window may be formed by milling or other suitable procedure either before or after the primary conduit assembly (20) is inserted into the primary borehole (34). Referring to Figure 1, in the preferred embodiment the second casing port (64) is formed after the primary conduit assembly (20) is inserted into the primary borehole (34).

The drilling of the second lateral borehole (46) will require that a second casing deflection device (66) such as a whipstock first be inserted in the casing string (22) adjacent to the casing window to deflect the drilling tool (55) out of the casing window. The second casing deflection device (66) may either be removed from the casing string (22) after the second lateral borehole (46) has been drilled and completed or it may be left in the casing string (22) permanently, Preferably the second casing deflection device (66) is left in the casing string (22) permanently in order to save the cost of removing it, and its presence may also be of assistance in the conduct of subsequent borehole operations from the production string (24).

After the second lateral borehole (46) has been drilled the second casing port (64) is part of and comprised by a second lateral junction (68) between the casing string (22) and the second lateral borehole (46).

In the preferred embodiment a second liner (70) is run into the second lateral borehole (46) to complete the second lateral borehole (46). The second liner (70) may be optional depending upon the requirements of the borehole. The second liner (70) is run into the second lateral borehole (46) by inserting the second liner (70) into the casing string (22) such that it exits the casing string (22) at the second lateral junction (68) and enters the second lateral borehole (46). The second liner (70) is preferably deflected into the second lateral borehole (46) by the second casing deflection device (66).

The second liner (70) is preferably connected with the casing string (22) at the second lateral junction (68) to establish connectivity between the primary borehole (34) and the second lateral borehole (46) and thus complete the second lateral junction (68). The connection between the casing string (22) and the second liner (70) may be established in any manner and may include equipment and apparatus which extend into the casing string (22). As a result, a high degree of connectivity may be established at the second lateral junction (68) without the need for special equipment for minimizing the obstruction of the casing string (22).

The borehole communicates with the casing string (22) through the second casing port (64). More specifically, the second lateral borehole (46) communicates with the casing string (22) through the second casing port (64).

When the second primary conduit junction (28) is opened the second casing port (64), the casing string (22), the second primary conduit junction (28) and the production string (24) define a second communication path (72) through the primary conduit assembly (20). Referring to Figure 1, in the preferred embodiment the second primary conduit junction (28) may be opened by removing the isolation sleeve (42) which is covering it. Alternatively, the second primary conduit junction (28) may be simultaneously formed and opened by milling or other suitable procedure.

In the preferred embodiment, the second casing port (64) and thus the second lateral junction (68) is located relative to the second primary conduit junction (28) so as to facilitate the conduct from the production string (24) of borehole operations in the second lateral borehole (46) via the second primary conduit junction (28).

The second communication path (72) is further defined in the preferred embodiment by a second casing sealing device (74) located proximally of the second primary conduit junction (28) and the second casing port (64). The second casing sealing device (74) may be comprised of any suitable packer, bridge plug or other structure or apparatus which is capable of sealing the casing string (22). The second casing sealing device (74) may be removable or may be a relatively permanent installation.

The function of the second casing sealing device (74) is first, to isolate the second communication path (72) from that portion of the casing string (22) which is proximal to the second casing sealing device (74) and second, to prevent the second communication path (72) from being contaminated by debris generated during drilling and completion of the third lateral borehole (48). The second casing sealing device (74) is installed in the casing string (22) after the second liner (70) has been inserted in the second lateral borehole (46) and preferably after the second lateral junction (68) has

been completed, although it may be possible to complete the second lateral junction (68) from the production string (24) after the second casing sealing device (74) has been installed.

Referring to Figure 3, it can be seen that the combined effect of the first casing sealing device (62) and the second casing sealing device (74) is to isolate the second communication path (72) in the casing string (22) both proximally and distally, since the casing sealing devices (62,74) straddle the second communication path (72).

The third lateral borehole (48) is located proximally of the second lateral borehole (46) and in the preferred embodiment is drilled after the second casing sealing device (74) has been installed in the casing string (22). The third lateral borehole (48) is drilled from a third casing port (76) and may be completed using the same sequence of steps as is the second lateral borehole (46). In other words, the above description pertaining to the second lateral borehole (46) is applicable to the third lateral borehole (48).

In this regard, the drilling of the third lateral borehole (48) will require a third casing deflection device (78). Furthermore, after the third lateral borehole (48) has been drilled the third casing port (76) is part of and comprised by a third lateral junction (80) between the casing string (22) and the third lateral borehole (48).

In the preferred embodiment a third liner (82) may be run into the third lateral borehole (48) to complete the third lateral borehole (48) in the same way that the second liner (70) is run into the second lateral borehole (46). The third liner (82) is then preferably connected with the casing string (22) at the third lateral junction (80) to

establish connectivity between the primary borehole (34) and the third lateral borehole (48) in a similar manner as is the case with the second lateral junction (68).

When the third primary conduit junction (30) is opened the third casing port (76), the casing string (22), the third primary conduit junction (30) and the production string (24) define a third communication path (84) through the primary conduit assembly (20). The third communication path (84) is further defined in the preferred embodiment by a third casing sealing device (86) located proximally of the third primary conduit junction (30) and the third casing port (76). The third casing sealing device (86) is installed in the casing string (22) after the third liner (82) has been inserted in the third lateral borehole (48) and preferably after the third lateral junction (80) has been completed.

Referring to Figure 3, it can be seen that the combined effect of the second casing sealing device (74) and the third casing sealing device (86) is to isolate the third communication path (84) in the casing string (22) both proximally and distally, since the casing sealing devices (74,86) straddle the third communication path (84).

The fourth lateral borehole (50) is located proximally of the third lateral borehole (48) and in the preferred embodiment is drilled after the third casing sealing device (86) has been installed in the casing string (22). The fourth lateral borehole (50) is drilled from a fourth casing port (88) and may be completed using the same sequence of steps as is the second lateral borehole (46). In other words, the above description pertaining to the second lateral borehole (46) is applicable to the fourth lateral borehole (50).

In this regard, the drilling of the fourth lateral borehole (50) will require a fourth casing deflection device (90). Furthermore, after the fourth lateral borehole (50) has been drilled the fourth casing port (88) is part of and comprised by a fourth lateral junction (92) between the casing string (22) and the fourth lateral borehole (50).

In the preferred embodiment a fourth liner (94) may be run into the fourth lateral borehole (50) to complete the fourth lateral borehole (50) in the same way that the second liner (70) is run into the second lateral borehole (46). The fourth liner (94) is then preferably connected with the casing string (22) at the fourth lateral junction (92) to establish connectivity between the primary borehole (34) and the fourth lateral borehole (50) in a similar manner as is the case with the second lateral junction (68).

When the fourth primary conduit junction (32) is opened the fourth casing port (88), the casing string (22), the fourth primary conduit junction (32) and the production string (24) define a fourth communication path (96) through the primary conduit assembly (20). The fourth communication path (96) is further defined in the preferred embodiment by a fourth casing sealing device (98) located proximally of the fourth primary conduit junction (32) and the fourth casing port (88). The fourth casing sealing device (98) is installed in the casing string (22) after the fourth liner (94) has been inserted in the fourth lateral borehole (50) and preferably after the fourth lateral junction (92) has been completed.

Referring to Figure 3, it can be seen that the combined effect of the third casing sealing device (86) and the fourth casing sealing device (98) is to isolate the fourth communication path (96) in the casing string (22) both proximally and distally, since the casing sealing devices (86,98) straddle the fourth communication path (96).

Although described above with four communication paths, the primary conduit assembly (20) may provide any number of communication paths as may be practical or necessary for the particular borehole design. It is also possible for one or more communication paths not to be associated with a lateral borehole. For example, a casing port may communicate with the primary borehole instead of with a lateral borehole, in which case the casing port may be comprised simply of a casing window or other perforation or perforations defined by the casing string. As a result, lateral boreholes as described above may be separated by one or more communication paths which are not associated with a lateral borehole.

There are a number of advantages to the borehole configuration depicted in Figure 3.

First, each lateral junction (56,68,80,92) may be completed as if the borehole were a single lateral borehole, since it is not necessary to be able to move equipment through the casing string (22) distally of a lateral junction (56,68,80,92) after the lateral junction has been completed. This feature simplifies the drilling of lateral boreholes, since equipment such as casing deflection devices (66,78,90) may be left in the casing string (22) after use. This feature also simplifies the completion of lateral junctions (56,68,80,92) and potentially improves their quality since connections between lateral liners (58,70,82,94) and the casing string (22) may extend into the casing string (22).

Second, production of fluids from a plurality of communication paths (60,72,84,96) may easily be conducted simultaneously via the production string (24) and may be controlled independently by the selective opening and closing of the primary conduit junctions (26,28,30,32). Furthermore, the production string (24) may provide for commingling of the various communication paths (60,72,84,96) or may be equipped

with completion apparatus to provide for segregation of the communication paths through the production string (24). This feature provides for a great deal of flexibility in borehole design without complicating the drilling and completion of the lateral junctions (56,68,80,92).

Referring to Figure 2, a third advantage of the configuration of Figure 3 is that fluids may be produced from the borehole via the production string (24) from one or more communication paths (60,72,84,96) while drilling is taking place via the casing string (22) proximally of the producing communication paths (60,72,84,96). In the preferred embodiment as shown in Figure 2 this feature is made possible by opening one or more of those primary conduit junctions (26,28,30,32) which are distal to the most proximal casing sealing device (62,74,86,98) while maintaining closed the primary conduit junctions (26,28,30,32) which are proximal to the most proximal casing sealing device (62,74,86,98).

Referring to Figure 5, a fourth advantage of the configuration of Figure 3 is that fluids may be produced from the borehole via the production string (24) from one or more communication paths (60,72,84,96) while borehole operations are being conducted in one or more lateral boreholes (44,46,48,50) via the production string (24). In the preferred embodiment as shown in Figure 5 this feature can be achieved by inserting equipment (100) into the production string (24) through the wellhead (not shown) while production of fluids is ongoing and then directing the equipment (100) to the desired lateral borehole (44,46,48,50) in order to conduct the borehole operations.

Typically, the direction of such equipment (100) into the desired lateral borehole (44,46,48,50) will require that a production string deflection device (102) such as a whipstock or other suitable structure or apparatus first be inserted in the production string (24) and temporarily landed adjacent to one of the primary conduit

junctions (26,28,30,32) in order to guide the equipment (100) into the desired lateral borehole (44,46,48,50). Once the equipment (100) has been directed into the desired lateral borehole (44,46,48,50), it may if required be landed into a polished bore receptacle (PBR) (104) or similar device in order to isolate the lateral borehole (44,46,48,50) from the rest of the borehole.

If the production string deflection device (102) does not completely prevent the flow of fluid past it, production of fluid from communication paths (60,72,84,96) originating both proximally and distally of the production string deflection device (102) can be continued while the borehole operations are being conducted. If the production string deflection device (102) does completely prevent the flow of fluid past it, then production of fluid will be possible only from communication paths (60,72,84,96) originating proximally of the production string deflection device (102).

Once the borehole operations have been completed, the equipment (100) and the production string deflection device (102) may be removed from the production string (24).

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. An apparatus for use in completing a borehole, the borehole comprising a primary borehole, the apparatus comprising a primary conduit assembly, the primary conduit assembly being comprised of:

(a) a tubular casing string extending into the primary borehole from a borehole entrance location;

(b) a tubular production string extending alongside the casing string and into the primary borehole from the borehole entrance location; and

(c) at least one primary conduit junction contained within the primary borehole, wherein the primary conduit junction provides for communication between the casing string and the production string.

2. The apparatus as claimed in claim 1 wherein the casing string defines at least one casing port for providing communication between the borehole and the casing string.

3. The apparatus as claimed in claim 2 wherein the primary conduit assembly is comprised of a plurality of longitudinally spaced primary conduit junctions and wherein the casing string is comprised of a plurality of longitudinally spaced casing ports, further comprising a plurality of communication paths between the casing ports and the production string, wherein each of the communication paths is defined by one of the casing ports, the casing string, one of the primary conduit junctions and the production string.

4. The apparatus as claimed in claim 3, further comprising a plurality of casing sealing devices located in the casing string, for sealing the casing string to isolate the communication paths from each other in the casing string.

5. The apparatus as claimed in claim 4 wherein at least one of the casing ports is comprised by a lateral junction between the primary borehole and a lateral borehole.

6. The apparatus as claimed in claim 5 wherein each of the lateral junctions is located relative to one of the primary conduit junctions so as to facilitate the conduct from the production string of borehole operations in the lateral borehole via the primary conduit junction.

7. The apparatus as claimed in claim 6, further comprising a casing deflection device located in the casing string adjacent to at least one of the lateral junctions, for deflecting objects from the casing string into the lateral borehole.

8. The apparatus as claimed in claim 7 wherein the communication paths are commingled in the production string.

9. A method for use in drilling and completing a borehole, the borehole comprising a primary borehole, the method comprising the following steps:

(a) inserting into the primary borehole a primary conduit assembly comprising a tubular casing string and a tubular production string so that the casing string and the production string extend alongside each other from a borehole entrance location;

(b) drilling a first lateral borehole by inserting a drilling tool into the casing string at the borehole entrance location such that the drilling tool exits the

casing string at a first casing port defined by the casing string so that the first casing port is comprised by a first lateral junction; and

(c) removing the drilling tool from the casing string.

10. The method as claimed in claim 9, further comprising the step of cementing the primary conduit assembly in the primary borehole.

11. The method as claimed in claim 10, further comprising the step of inserting a first casing deflection device in the casing string adjacent to the first casing port before the step of drilling the first lateral borehole.

12. The method as claimed in claim 10, further comprising the step of forming the first casing port before the step of drilling the first lateral borehole.

13. The method as claimed in claim 10, further comprising the step of running a first liner into the first lateral borehole by inserting the first liner into the casing string such that it exits the casing string at the first lateral junction and enters the first lateral borehole and further comprising the step of connecting the first liner to the casing string.

14. The method as claimed in claim 10, further comprising the step of opening a first primary conduit junction contained within the primary borehole to establish a first communication path between the first lateral junction and the production string.

15. The method as claimed in claim 14 wherein the first primary conduit junction is preformed in the primary conduit assembly and wherein the step of opening the first primary conduit junction is comprised of removing a first isolation sleeve from the primary conduit assembly.

16. The method as claimed in claim 14, further comprising the step of sealing the casing string with a first sealing device proximally of the first primary conduit junction and the first lateral junction.

17. The method as claimed in claim 16, further comprising the step of drilling a second lateral borehole by inserting the drilling tool into the casing string at the borehole entrance location such that it exits the casing string at a second casing port defined by the casing string and located proximally of the first sealing device so that the second casing port is comprised by a second lateral junction and further comprising the step of removing the drilling tool from the casing string.

18. The method as claimed in claim 17, further comprising the step of inserting a second casing deflection device in the casing string adjacent to the second casing port before the step of drilling the second lateral borehole.

19. The method as claimed in claim 17, further comprising the step of forming the second casing port before the step of drilling the second lateral borehole.

20. The method as claimed in claim 17, further comprising the step of running a second liner into the second lateral borehole by inserting the second liner into the casing string such that it exits the casing string at the second lateral junction and enters the second lateral borehole and further comprising the step of connecting the second liner to the casing string.

21. The method as claimed in claim 17, further comprising the step of opening a second primary conduit junction contained within the primary borehole to establish a second communication path between the second lateral junction and the production string.

22. The method as claimed in claim 17 wherein the second primary conduit junction is preformed in the primary conduit assembly and wherein the step of opening the second primary conduit junction is comprised of removing a second isolation sleeve from the primary conduit assembly.

23. The method as claimed in claim 21, further comprising the step of sealing the casing string with a second sealing device proximally of the second primary conduit junction and the second lateral junction.

24. The method as claimed in claim 16, further comprising the step of producing a fluid from the borehole via the first communication path and the production string.

25. The method as claimed in claim 17, further comprising the step of producing a fluid from the borehole via the first communication path and the production string.

26. The method as claimed in claim 21 wherein the step of producing the fluid from the borehole via the first communication path and the production string is performed at the same time as the step of drilling the second lateral borehole.

FIGURE 1

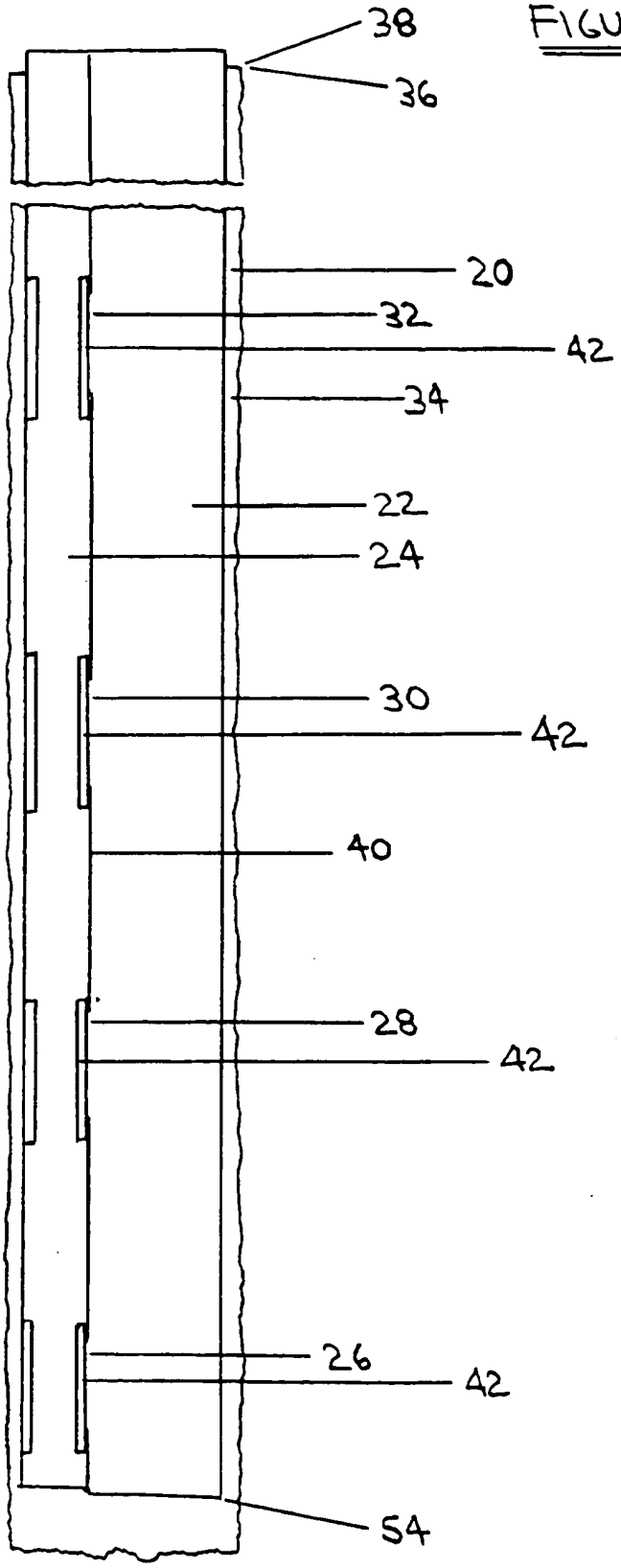

FIGURE 2

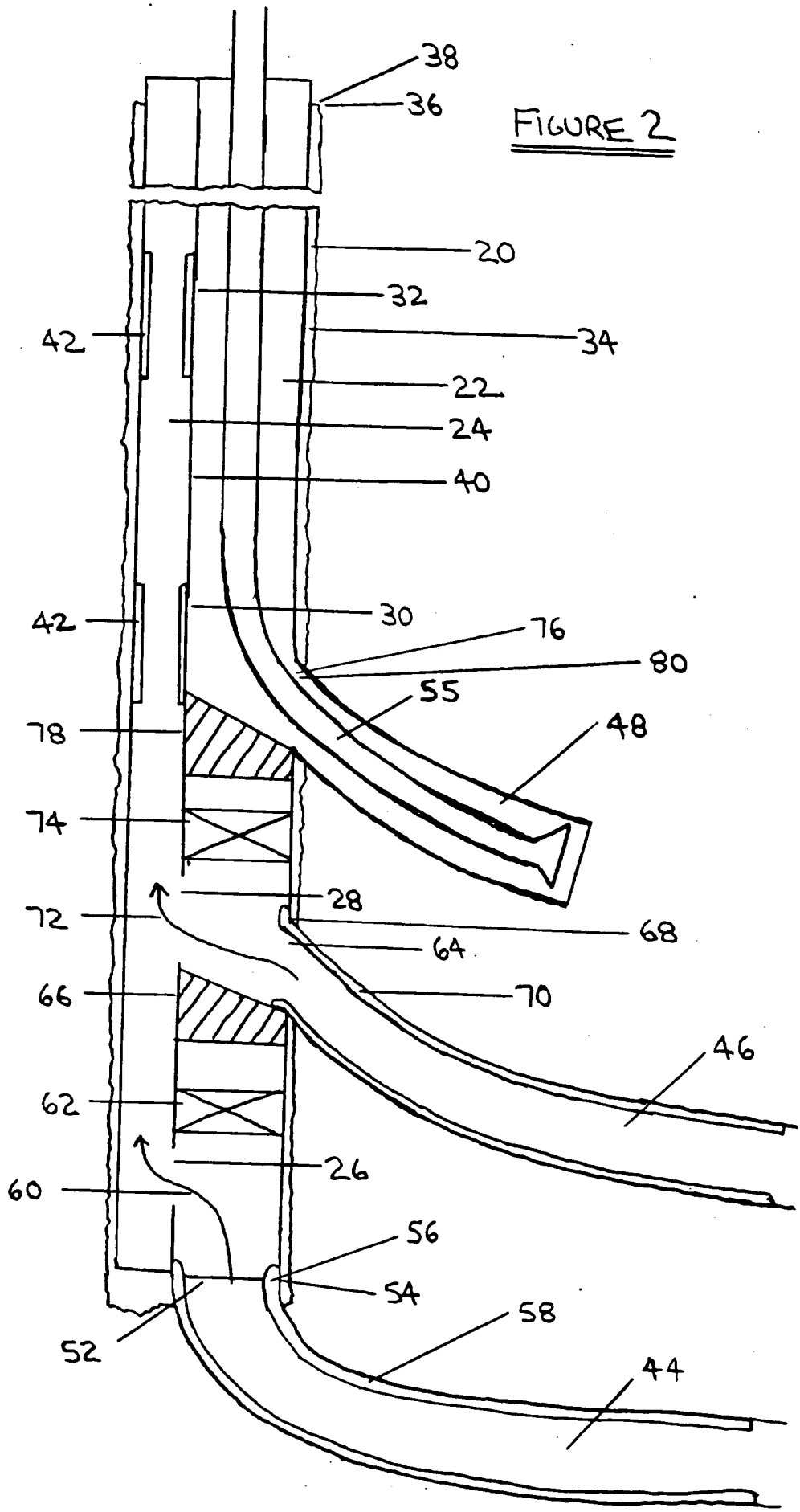
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FIGURE 3

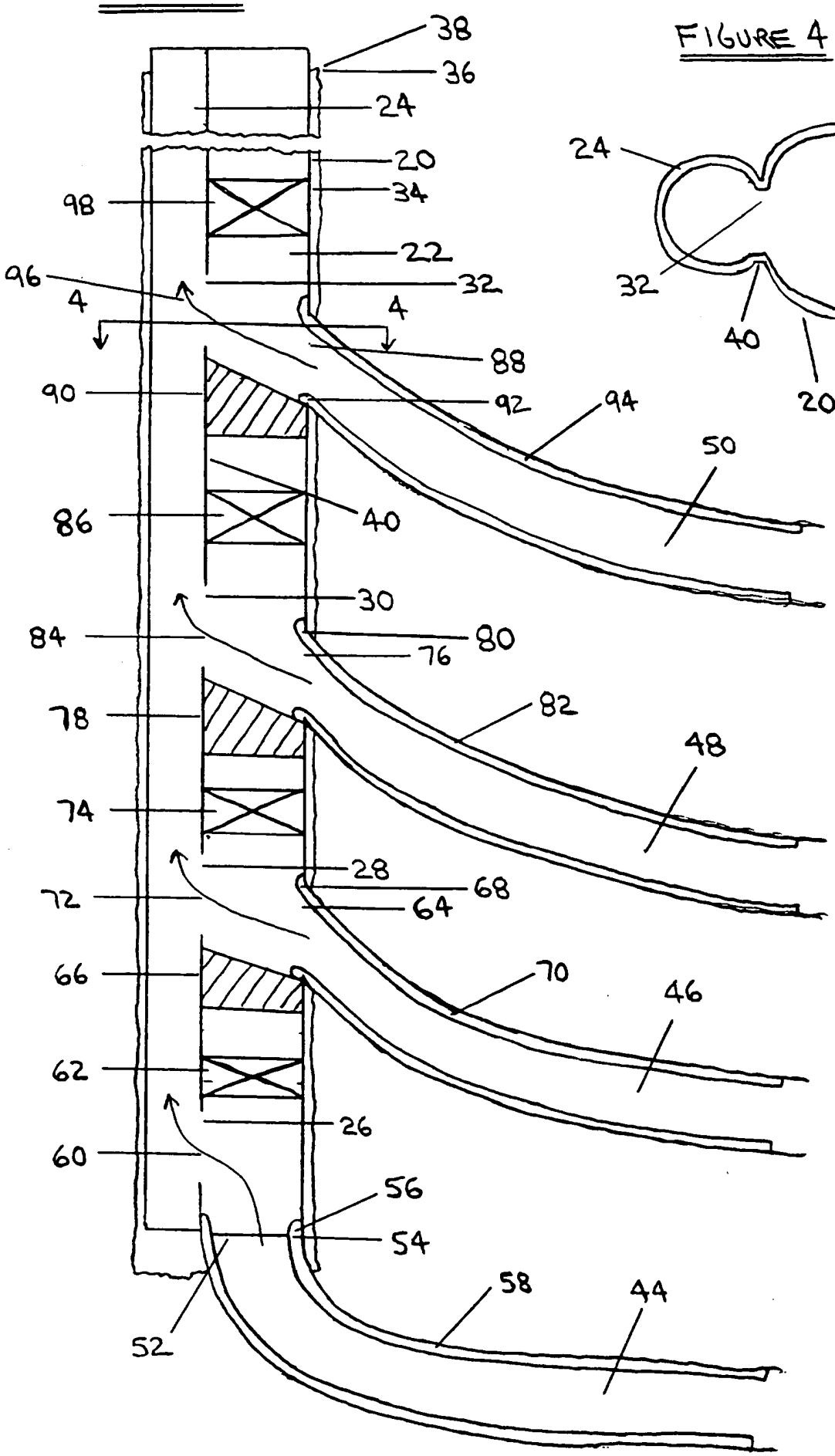
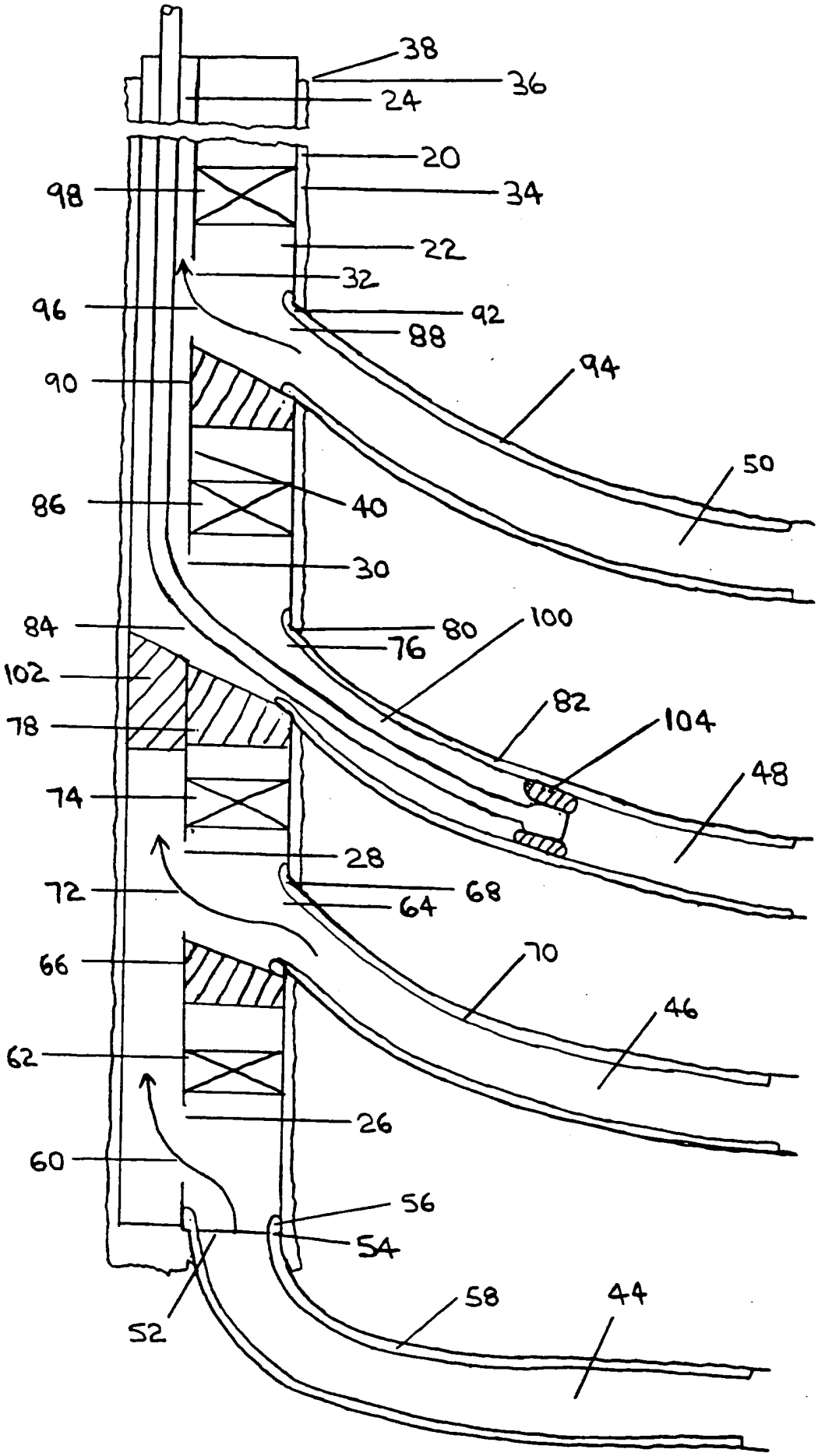


FIGURE 4

FIGURE 5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